

## **IN THE CLAIMS**

Please amend the claims as indicated:

- 1     1.     **canceled** An apparatus for drilling a borehole and determining a parameter of  
2           interest of a formation surrounding the borehole, said apparatus comprising:  
3           (a)     a longitudinal member for rotating a drill bit and adapted to be conveyed  
4                    in the borehole;  
5           (b)     a nuclear magnetic resonance (NMR) sensor assembly including at least  
6                    one member slidably coupled to and spaced apart from said longitudinal  
7                    member defining a flow path for drilling fluid therebetween, said NMR  
8                    sensor assembly producing a pulsed RF field for obtaining measurements  
9                    indicative of the parameter of interest of the formation, said RF field  
10                  characterized by a plurality of parameters; and  
11           (c)     a downhole processor for varying at least one parameter of the pulsed RF  
12                  field.

- 13  
1     2.     **canceled** The apparatus of claim 1 wherein the pulsed RF field comprises a pulse  
2           sequence of the form:

3           
$$\left[ TW_i - 90_{\pm\pi/2} - (\tau - X - \tau - echo)_j \right]_i$$

- 4           wherein  $TW$  is a wait time,  $90_{\pm\pi/2}$  refers to a phase alternated  $90^0$  tipping pulse  
5           ,  $X$  is a refocusing pulse with a tipping angle that lies between  $90^0$  and  $180^0$ ,  $j$  is

6 the number of echos observed,  $i$  is a number of repetitions, and  $2\tau$  is an interecho  
7 spacing, and wherein the parameter of interest of the pulsed RF field is selected  
8 from the group consisting of: (i) the tipping angle of the refocusing pulse, (ii) the  
9 number of echos  $j$ , (iii) the number of repetitions  $i$ , (iv) the interecho spacing, and  
10 (v) the wait time.

11

1 3. **canceled** The apparatus of claim 1 wherein the sensor assembly further  
2 comprises:

3 at least one clamping device for engaging the borehole to clamp the at  
4 least one member to the borehole.

5

1 4. **canceled** The apparatus of claim 1 wherein the longitudinal member is a segment  
2 of drill pipe.

3

1 5. **canceled** The apparatus of claim 1 wherein the longitudinal member is a shaft on  
2 a downhole directional drilling assembly.

3

1 6. **canceled** The apparatus of claim 1 further comprising:  
2 at least one thruster connected to the sensor assembly for providing axial  
3 decoupling of the at least one member of the sensor assembly from the  
4 longitudinal member and for dampening vibrations to the at least one member.

5

- 1 7. **canceled** The apparatus of claim 1 wherein the NMR sensor assembly is operated  
2 in one of (i) a clamped mode, (ii) a rotating mode, (iii) in a changing mode, and,  
3 (iv) a tripping mode.  
4
- 1 8. **canceled** The apparatus of claim 1 further comprising a drilling sensor module for  
2 making measurements relating to a drilling parameter selected from the group  
3 consisting of (i) a bit bounce, (ii) stick-slip of the longitudinal member, (iii)  
4 backward rotation, (iv) torque, (v) shocks, (vi) borehole and annulus pressure, and  
5 (vii) acceleration.  
6
- 1 9. **canceled** The apparatus of claim 1 further comprising a formation evaluation  
2 sensor for making measurements indicative of at least one of (i) a lithology of the  
3 formation, and, (ii) a fluid content of the formation.  
4
- 1 10. **canceled** The apparatus of claim 1 further comprising a telemetry module for  
2 communicating signals to and from a surface location.  
3
- 1 11. **canceled** The apparatus of claim 1 wherein the processor provides a quality  
2 control (QC) diagnostic based on at least one of (i) a signal from a motion sensor,  
3 (iii) a sum of echos (SE) produced by the NMR sensor assembly.  
4
- 1 12. **canceled** The apparatus of claim 11 wherein the processor uses said QC

2 diagnostic for at least one of (i) discarding a subset of said measurements, (ii)  
3 replacing a subset of said measurements with another subset of said  
4 measurements, (iii) zeroing out partial echo trains.

1 13. **canceled** The apparatus of claim 1 wherein the processor performs an averaging  
2 of measurements within a time window.

1 14. **canceled** The apparatus of claim 13 wherein the averaging is one of (i) an  
2 unweighted averaging, and, (ii) a weighted averaging.

1 15. **canceled** The apparatus of claim 1 wherein the processor combines data with  
2 different phases of the tipping pulse for reducing an error in the measurements.

1 16. **canceled** The apparatus of claim 1 wherein the processor applies a stimulated  
2 echo correction to said measurements.

1 17. **canceled** The apparatus of claim 16 wherein said stimulated echo correction is  
2 determined by at least one of (i) a temperature of the formation, (ii) an intensity  
3 of the RF field, (iii) a bandwidth of the tipping pulse, and, (iv) a bandwidth of the  
4 refocusing pulse.

1 18. **canceled** The apparatus of claim 1 wherein said measurements further comprise

2 two channels of data, the processor further determining a corrected measurement  
3 based on measurements on said two channels and a phase angle therebetween.  
4

1 19. **canceled** The apparatus of claim 1 wherein the processor applies a calibration to  
2 said measurements, said calibration based upon measurements made with the  
3 NMR sensor assembly in a medium of known porosity.  
4

1 20. **canceled** The apparatus of claim 19 wherein said calibration is dependent upon a  
2 temperature of the medium.  
3

1 21. **canceled** The apparatus of claim 1 wherein the processor applies a correction for  
2 salinity of a fluid in the formation.  
3

1 22. **canceled** The apparatus of claim 2 wherein the processor stacks data acquired in a  
2 plurality of repetitions.  
3

1 23. **canceled** The apparatus of claim 1 wherein the processor applies a  
2 multiexponential fit to said measurements.  
3

1 24. **canceled** The apparatus of claim 1 wherein the processor applies a correction  
2 based upon a temperature of the formation to said measurements.  
3

- 1 25. **canceled** The apparatus of claim 10 wherein the processor varies the at least one  
2 parameter of the pulsed RF field at least partially in response to a control signal  
3 from the surface location.  
4
- 1 26. **canceled** The apparatus of claim 9 wherein the processor further comprises an  
2 expert system for determining from said measurements of the formation  
3 evaluation sensor at least one of (A) the lithology of the formation, and, (ii) the  
4 fluid content of the formation.  
5
- 1 28. **canceled** The apparatus of claim 26 wherein the processor varies the at least one  
2 parameter of the pulsed RF field at least partially in response to the at least one of  
3 (A) the determined lithology of the formation, and, (B) the determined fluid  
4 content of the formation.  
5
- 1 29. **canceled** The apparatus of claim 28 wherein the pulsed RF field comprises a  
2 pulse sequence of the form:  
3  
4  
5  
6  
7
- $$\left[ TW_i - 90_{\pm\pi/2} - (\tau - X - \tau - echo)_j \right]_i$$
- wherein  $TW$  is a wait time,  $90_{\pm\pi/2}$  refers to a phase alternated  $90^0$  tipping pulse ,  
 $X$  is a refocusing pulse with a tipping angle that lies between  $90^0$  and  $180^0$ ,  $j$  is the  
number of echos observed,  $i$  is a number of repetitions, and  $2\tau$  is an interecho  
spacing, and wherein the parameter of interest of the pulsed RF field is selected

8 from the group consisting of: (I) the tipping angle of the refocusing pulse, (II) the  
9 number of echos  $j$ , (III) the number of repetitions  $i$ , (IV) the interecho spacing,  
10 and, (V) the wait time.

11

1 30. **canceled** The apparatus of claim 1 wherein the NMR sensor assembly is operated  
2 in a clamped mode and the processor varies the at least one parameter in response  
3 to a rate of penetration (ROP) of the drillbit.

4

1 31. **canceled** The apparatus of claim 1 wherein the NMR sensor assembly is operated  
2 in one of (i) a rotating mode, (ii) a changing mode, and, (iii) a tripping mode, and  
3 the processor varies the at least one parameter in response to a signal from a  
4 motion sensor on the apparatus.

5

1 32. **canceled** The apparatus of claim 31 wherein the NMR sensor assembly is  
2 operated in a tripping mode and the processor further applies a correction to said  
3 measurements based upon a signal from a motion sensor on the apparatus.

4

1 33. **canceled** The apparatus of claim 31 wherein the processor processes said  
2 measurements in one of (i) based upon a signal from a surface processor, and, (ii)  
3 independently of the surface processor.

4

1 34. **canceled** The apparatus of claim 1 wherein the processor performs at least one of

2 (i) deleting a subset of said measurements, (ii) replacing a subset of said  
3 measurements, and, (iii) zeroing a subset of echos in an echo train.

4

1 35. **canceled** The apparatus of claim 1 wherein the processor determines a calibration  
2 factor relating said measurements to a porosity of the formation, said calibration  
3 factor being related to a temperature of the formation,

4

1 36. **canceled** The apparatus of claim 1 wherein the processor determines from said  
2 measurements the parameter of interest, said parameter of interest being at least  
3 one of (i) a total porosity, (ii) an effective porosity, (iii) a volume fraction of clay  
4 bound water, and, (iii) and a volume fraction of bound water irreducible.

5

1 37. **canceled** An apparatus for drilling a borehole and determining a parameter of  
2 interest of a formation surrounding the borehole, said apparatus comprising:

3 (a) a longitudinal member for rotating a drill bit and adapted to be conveyed  
4 in the borehole;

5 (b) a nuclear magnetic resonance (NMR) sensor assembly producing a pulsed  
6 RF field for obtaining measurements indicative of the parameter of interest  
7 of the formation, said RF field characterized by a plurality of parameters;  
8 and

9 (c) a downhole processor including an expert system for controlling at least  
10 one parameter of the pulsed RF field.



11

- 1 38. **canceled** The apparatus of claim 37 wherein the pulsed RF field comprises a  
2 pulse sequence of the form:

3 
$$\left[ TW_i - 90_{\pm\pi/2} - (\tau - X - \tau - echo)_j \right]_i$$

4 wherein  $TW$  is a wait time,  $90_{\pm\pi/2}$  refers to a phase alternated  $90^0$  tipping pulse ,  
5  $X$  is a refocusing pulse with a tipping angle that lies between  $90^0$  and  $180^0$ ,  $j$  is the  
6 number of echos observed,  $i$  is a number of repetitions, and  $2\tau$  is an interecho  
7 spacing, and wherein the parameter of interest of the pulsed RF field is selected  
8 from the group consisting of: (i) the tipping angle of the refocusing pulse, (ii) the  
9 number of echos  $j$ , (iii) the number of repetitions  $i$ , (iv) the interecho spacing, and  
10 (v) the wait time.

11

- 1 39. **canceled** The apparatus of claim 37 wherein the NMR sensor assembly further  
2 comprises:

- 3 (i) a member slidably coupled to and spaced apart from said longitudinal  
4 member defining a flow path for drilling fluid therebetween; and  
5 (ii) at least one clamping device for engaging the borehole to clamp said  
6 member to the borehole.

7

- 1 40. **canceled** The apparatus of claim 37 wherein the longitudinal member selected  
2 from the group consisting of (i) a segment of drill pipe, and, (ii) a shaft on a

3 downhole directional drilling assembly.

4

1 41. **canceled** The apparatus of claim 37 further comprising a telemetry module for  
2 communicating signals to and from a surface location

1 42. **canceled** The apparatus of claim 38 wherein the processor applies a stimulated  
2 echo correction to said measurements, said stimulated echo correction determined  
3 by at least one of (i) a temperature of the formation, (ii) an intensity of the RF  
4 field, (iii) a bandwidth of the tipping pulse, and, (iv) a bandwidth of the  
5 refocusing pulse.

6

1 43. **canceled** The apparatus of claim 37 further comprising a formation evaluation  
2 sensor for making measurements indicative of at least one of (i) a lithology of the  
3 formation, and, (ii) a fluid content of the formation.

4

1 44. **canceled** The apparatus of claim 43 further comprising using the expert system  
2 for determining from said measurements of the formation evaluation sensor at  
3 least one of (A) the lithology of the formation, and, (ii) the fluid content of the  
4 formation.

5

1 45. **canceled** A method of using a bottom hole assembly (BHA) conveyed in a  
2 borehole of an earth formation for determining a parameter of interest of the  
3 formation comprising:

- 4 (a) using a longitudinal member on the BHA for penetrating the formation;  
5 (b) using a nuclear magnetic resonance (NMR) sensor assembly on the BHA  
6 for producing a pulsed RF field for obtaining measurements indicative of  
7 the parameter of interest of the formation, said RF field characterized by a  
8 plurality of parameters, said NMR assembly including at least one member  
9 slidably coupled to and spaced apart from said longitudinal member  
10 defining a flow path for drilling fluid therebetween; and  
11 (c) using a downhole processor on the BHA for varying at least one  
12 parameter of the pulsed RF field.

13

- 1 46. **canceled** The method of claim 45 wherein producing the pulsed RF field  
2 comprises pulsing a transmitter on the sensor assembly with a pulse sequence of  
3 the form:

4 
$$\left[ TW_i - 90_{\pm\pi/2} - (\tau - X - \tau - echo)_j \right]_i$$

- 5 wherein  $TW$  is a wait time,  $90_{\pm\pi/2}$  refers to a phase alternated  $90^0$  tipping pulse ,  
6  $X$  is a refocusing pulse with a tipping angle that lies between  $90^0$  and  $180^0$ ,  $j$  is the  
7 number of echos observed,  $i$  is a number of repetitions, and  $2\tau$  is an interecho  
8 spacing, and wherein the parameter of interest of the pulsed RF field is selected  
9 from the group consisting of: (i) the tipping angle of the refocusing pulse, (ii) the  
10 number of echos  $j$ , (iii) the number of repetitions  $i$ , (iv) the interecho spacing, and  
11 (v) the wait time.

12

1 47. **canceled** The method of claim 45 further comprising using at least one clamping  
2 device for engaging the borehole to clamp the at least one member to the  
3 borehole.

4

1 48. **canceled** The method of claim 45 further comprising using at least one thruster  
2 connected to the sensor assembly for providing axial decoupling of the at least one  
3 member of the sensor assembly from the longitudinal member and for dampening  
4 vibrations to the at least one member.

5

1 49. **canceled** The method of claim 45 further comprising using a drilling sensor  
2 module for making measurements relating to a drilling parameter selected from  
3 the group consisting of (i) a bit bounce, (ii) stick-slip of the longitudinal member,  
4 (iii) backward rotation, (iv) torque, (v) shocks, (vi) borehole and annulus pressure,  
5 and (vii) acceleration.

6

1 50. **canceled** The method of claim 45 further comprising using a formation evaluation  
2 sensor for making measurements indicative of at least one of (i) a lithology of the  
3 formation, and, (ii) a fluid content of the formation.

4

1 51. **canceled** The method of claim 45 further comprising using a telemetry module on  
2 the BHA for communicating signals to and from a surface location.

3

1 52. **canceled** The method of claim 45 further comprising using the processor for  
2 providing a quality control (QC) diagnostic based on at least one of (i) a signal  
3 from a motion sensor, (iii) a sum of echos (SE) produced by the NMR sensor  
4 assembly.

5

1 53. **canceled** The method of claim 52 further comprising using the processor, based  
2 on said QC diagnostic, for at least one of (i) discarding a subset of said  
3 measurements, (ii) replacing a subset of said measurements with another subset of  
4 said measurements, (iii) zeroing out partial echo trains

5

1 54. **canceled** The method of claim 45 further comprising using the processor for  
2 combining measurements with different phases of the tipping pulse for reducing  
3 an error therein.

4

1 55. **canceled** The method of claim 45 further comprising using the processor for  
2 applying a stimulated echo correction to said measurements.

3

1 56. **canceled** The method of claim 45 wherein said measurements further comprise  
2 two channels of data, the method further comprising using the processor for  
3 determining a corrected measurement based on measurements on said two  
4 channels and a phase angle therebetween.

5

1 57. **canceled** The method of claim 45 further comprising using the processor for  
2 calibrating said measurements, said calibration based upon measurements made  
3 with the NMR sensor assembly in a medium of known porosity.

4

1 58. **canceled** The method of claim 45 further comprising using the processor for  
2 applying a multiexponential fit to said measurements.

3

1 59. **canceled** The method of claim 51 further comprising sending a control signal  
2 from the surface location to the processor and varying the at least one parameter  
3 of the pulsed RF field in response thereto.

4

1 60. **canceled** The method of claim 50 wherein the processor further comprises an  
2 expert system for determining from said measurements of the formation  
3 evaluation sensor at least one of (A) the lithology of the formation, and, (ii) the  
4 fluid content of the formation.

5

1 61. **canceled** The method of claim 60 wherein the expert system varies the at least  
2 one parameter of the pulsed RF field at least partially in response to one (A) the  
3 lithology of the formation, and, (ii) the fluid content of the formation.

4

1 62. **canceled** The method of claim 45 further comprising:

- 2 (i) operating the NMR sensor assembly in a clamped mode,
- 3 (ii) determining a rate of penetration of the longitudinal member, and
- 4 (iii) varying the at least one parameter of the RF field in response to said rate
- 5 of penetration (ROP) of the drillbit.

6

1 63. **canceled** The method of claim 45 further comprising using the processor for

2 determining from said measurements the parameter of interest, said parameter of

3 interest being at least one of (i) a total porosity, (ii) an effective porosity, (iii) a

4 volume fraction of clay bound water, and, (iii) and a volume fraction of bound

5 water irreducible.

6

1 64. **canceled** A method of using a bottom hole assembly (BHA) conveyed in a

2 borehole of an earth formation for determining a parameter of interest of the

3 formation comprising:

- 4 (a) using a longitudinal member on the BHA for penetrating the formation;
- 5 (b) using a nuclear magnetic resonance (NMR) sensor assembly on the BHA
- 6 for producing a pulsed RF field for obtaining measurements indicative of
- 7 the parameter of interest of the formation, said RF field characterized by a
- 8 plurality of parameters; and
- 9 (c) using a downhole processor including an expert system for determining a
- 10 lithology of the formation and selecting at least one parameter of the pulsed
- 11 RF field based at least in part on the determined lithology.

12

- 1 65. **canceled** The method of claim 64 wherein producing the pulsed RF field  
2 comprises pulsing a transmitter on the sensor assembly with a pulse sequence of  
3 the form:

4 
$$\left[ TW_i - 90_{\pm\pi/2} - (\tau - X - \tau - echo)_j \right]_i$$

- 5 wherein  $TW$  is a wait time,  $90_{\pm\pi/2}$  refers to a phase alternated  $90^0$  tipping pulse ,  
6  $X$  is a refocusing pulse with a tipping angle that lies between  $90^0$  and  $180^0$ ,  $j$  is the  
7 number of echos observed,  $i$  is a number of repetitions, and  $2\tau$  is an interecho  
8 spacing, and wherein the parameter of interest of the pulsed RF field is selected  
9 from the group consisting of: (i) the tipping angle of the refocusing pulse, (ii) the  
10 number of echos  $j$ , (iii) the number of repetitions  $i$ , (iv) the interecho spacing, and  
11 (v) the wait time.

12

- 1 66. **canceled** The method of claim 64 further comprises:  
2 (i) using a member on the NMR assembly slidably coupled to and spaced  
3 apart from said longitudinal member defining a flow path for drilling fluid  
4 therebetween; and  
5 (ii) using at least one clamping device for engaging the borehole to clamp said  
6 member to the borehole.

7

- 1 67. **canceled** The method of claim 64 wherein the longitudinal member is selected



2 from the group consisting of (i) a segment of drill pipe, and, (ii) a shaft on a  
3 downhole directional drilling assembly.

4

1 68. **canceled** The method of claim 64 further comprising using a telemetry module on  
2 the BHA for communicating signals to and from a surface location.

3

1 69. **canceled** The method of claim 65 further comprising using the processor for  
2 applying a stimulated echo correction to said measurements, said stimulated echo  
3 correction determined by at least one of (i) a temperature of the formation, (ii) an  
4 intensity of the RF field, (iii) a bandwidth of the tipping pulse, and, (iv) a  
5 bandwidth of the refocusing pulse.

6

1 70. **canceled** The apparatus of claim 64 further comprising a formation evaluation  
2 sensor for making measurements indicative of at least one of (i) a lithology of the  
3 formation, and, (ii) a fluid content of the formation.

4

1 71. **canceled** The apparatus of claim 70 further comprising using the expert system  
2 for determining from said measurements of the formation evaluation sensor at  
3 least one of (A) the lithology of the formation, and, (ii) the fluid content of the  
4 formation.

5

1 72. **canceled** A method of using a bottom hole assembly (BHA) conveyed in a

2 borehole of an earth formation for determining a parameter of interest of the  
3 formation comprising:  
4 (a) using a longitudinal member on the BHA for penetrating the formation;  
5 (b) using a nuclear magnetic resonance (NMR) sensor assembly on the BHA  
6 for producing a pulsed RF field for obtaining measurements indicative of  
7 the parameter of interest of the formation, said RF field characterized by a  
8 plurality of parameters; and  
9 (c) using a downhole processor and for selecting at least one parameter of the  
10 pulsed RF field at least partially in response to a control signal sent to the  
11 processor from a surface location.

12

1 73. (new) An apparatus for drilling a borehole and determining a parameter of interest of  
2 a formation surrounding the borehole, said apparatus comprising:  
3 (a) a longitudinal member for rotating a drill bit and adapted to be conveyed  
4 in the borehole;  
5 (b) formation evaluation sensor on said longitudinal member for making  
6 measurements indicative of at least one of (A) a lithology of the formation,  
7 and, (B) a fluid content of the formation.  
8 (c) an expert system for determining from said measurements of the formation  
9 evaluation sensor at least one of (C) the lithology of the formation, and,  
10 (D) the fluid content of the formation.

11